I. C. 6531 October, 1931

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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MINING AND CRUSHING METHODS AND COSTS AT THE TIFFIN LIMESTONE QUARRY OF THE THURBER EARTHEN PRODUCTS CO., FORT WORTH, TEX.

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MINING AND CRUSHING METHODS AND COSTS AT THE TIFFIN LIMESTONE QUARRY OF THE THURBER EARTHEN PRODUCTS CO., FORT WORTH, TEX.[1]

By Dayton C. Bolin[2]

This paper is one of a series being prepared by the United States Bureau of Mines describing quarrying methods and costs at stone quarries throughout the United States. These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent operating expenditures only and not total production costs. It is recognized that publication of total production costs might in many instances cause embarrassment to individual producers as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of the methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scrope of the cost tabulations shall ensue.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance of J. R. Thoenen, mining engineer, United States Bureau of Mines, in the preparation of this paper. Acknowledgment is also made to E. R. Lederer, vice president in charge of the company's operations, through whose kindness the preparation of this paper was made possible. E. T. Eubank, superintendent of the quarry, and J. A. Hodges, quarry foremen, gave much of their time to this work. The cost data were compiled by the company's chief clerk, J. von Carlowitz.

BRIEF HISTORY AND EARLY DEVELOPMENT OF DISTRICT

The activity in the Ranger oil field of Eastland and Stephens Counties during 1918-19 created a demand for large quantities of crushed stone for highway construction, and at the same time it was predicted that the railroad would soon require ballast as part of an extension program to take care of the increase in business due to the oil discovery.

Some of the directors of the Texas Pacific Coal and Oil Co., the discoverer of the new oil field, saw attractive possibilities in the crushed-stone business, provided suitable rock could be obtained locally. Limestone was known to occur throughout the locality and one or two small quarries were operating, but no comprehensive investigation of limestone resources had been made. Such a survey was undertaken and as a result a suitable ledge of limestone was found near Ranger on the land of M. H. Hagaman at a place then known as Bull Creek but later called Tiffin when it became a station on the Texas & Pacific Railway. A company known as the Thurber Earthen Products Co. was organized to produce and sell crushed limestone.

Early in 1919 the building of a modern crushing plant and the opening of the quarry were begun. The plant started operation in September, 1920. The railroads soon became active buyers of the crushed stone and the anticipated output was readily realized. Numerous improvements in plant and organization have been made from time to time.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6531."

[2] One of the consulting engineers, U. S. Bureau of Mines, and chemical engineer, Texas Pacific Coal and Oil Co., Fort Worth, Tex.

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GEOLOGY

The rock quarried at Tiffin is a limestone containing about 52 per cent lime (CaO) largely in the form of carbonate. The overburden, which is a clayey soil varying in color from a light yellow to reddish or black, averages not more than a foot to 16 inches in depth over the whole quarry area. The limestone varies from 20 to 25 feet in thickness, - the average being about 23 feet. Below the limestone is a layer of shale that is 12 to 18 feet thick. The shale is supposed to cap another stratum of limestone, but there is no evidence at hand to support this supposition. The formation is fairly uniform throughout the quarry area.

Throughout the quarry joints or seams divide the limestone into blocks with overburden or clay filling the crevices between them. In some instances these joints extend down to the shale some 25 feet below; in other cases they run laterally, are irregular and broken, and do not extend so far. Their strike has a definite tendency to run south 30° west with considerable cross jointing at about right angles.

PHYSICAL CHARACTERISTICS

The limestone varies in color from a dark cream to a slate gray. This variation occurs uniformly at certain locations throughout the quarry, but the color of the stone has no material influence on its composition.

Physical tests of the stone made by the University of Texas gave results as follows:

Specific gravity	2.66	
Weight per cubic foot, pounds	166.	
Per cent wear (Deval test)	2.76	
French coefficient of wear	14.50	(high)
Coefficient of hardness (Dorry test)	14.10	
Toughness (Page impact test)	7.50	(low)
Cementing value	40.0	(good)
Crushing strength, on 2-inch cube, pounds per square inch	16,650	(high)

Chemical analyses of the quarry materials follow:

		Stone	Shale	Overbirden
Silica (SiO_2)	per cent	2.34	80.40	54.70
Iron oxide and alumina (Fe_2O_3 & Al_2O_3)	do.	2.06	14.20	15.50
Lime (CaO)	do.	52.80	0.67	3.90
Magnesia (MgO)	do.	0.50	0.62	2.80
Sulphate (SO_4)	do.	0.15	0.63	3.20

METHOD OF EXPLORATION

The property was tested by diamond-drill holes through the limestone at intervals of about every hundred feet. Because of the destruction of the main office by fire many of the old drilling records are not available, but the area, formation, and content of the deposit have been well surveyed and the latter is sufficient for a considerable number of years. Cost figures for exploration are not available.

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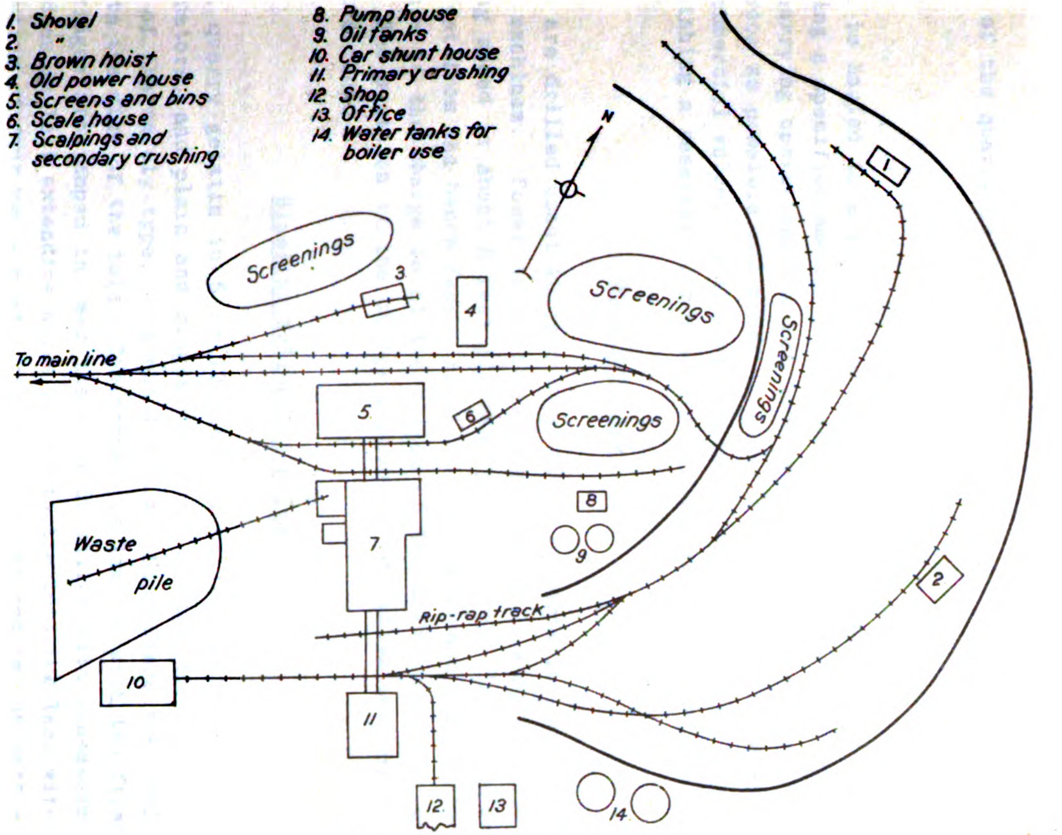
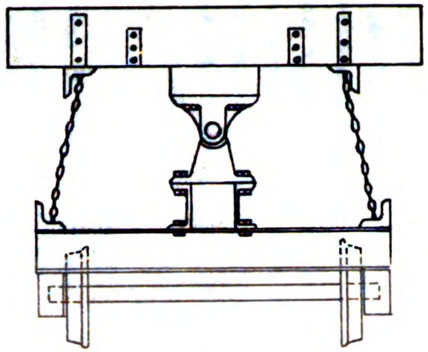
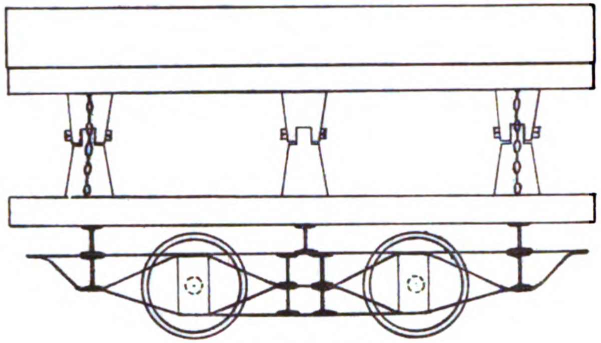


Figure 1.- General plan of quarry



END VIEW



SIDE ELEVATION

Figure 2.- Quarry dump car

SAMPLING AND ESTIMATION OF TONNAGES

No routine sampling is carried on, and physical and chemical analyses of the limestone are made only occasionally.

Ten sizes of stone are produced ranging from 3½ inches down to 3/16 inch in maximum diameter. Screen tests of the various sizes are made in the plant and by inspectors representing large buyers. The estimated tonnage unquarried is about 8,000,000 tons, which will suffice for 25 years at the present rate of production.

CHOICE OF METHODS

The overburden is removed by contract in wagons and motor trucks at 40 cents per square yard of surface stripped. Due to the shallow depth of the overburden, this has proved to be the least expensive method of stripping.

The stone is quarried by well drilling, blasting with dynamite, and loading on 6-yard dump cars with steam shovels. It is then hauled by two 18-ton locomotives to the primary crusher.

MINING METHODS

A general plan of the quarry is shown in Figure 1.

Stripping

The overburden is hauled to a valley about one-half mile away and dumped. Contracts are given for removing a specified amount and the contractor may use his judgment in its removal so long as quarrying operations are not inconvenienced. The contractor usually completes the job as soon as possible and moves to other work until he is needed again. The overburden has no commercial value. It is dumped into the valley with the idea of eventually damming it and furnishing a reservoir for water to be used in and around the quarry.

Well Drilling

Six-inch holes are drilled about 23 feet deep with two portable Loomis Clipper churn-type well-drilling machines. Power is furnished by a 50-hp., 4-cylinder Buda gasoline motor. The drilling speed is about 8 feet per hour per machine. The holes are spaced 10 feet apart and 10 feet from the bench face. About 35 holes are shot simultaneously, and as a rule three-quarters of the charge is at the bottom of the hole, the other quarter being placed further up. The position of the charge depends on the prevalence of the joints and the uniformity of the rock.

Blasting Well-Drill Holes

Sixty-per cent quarry gelatin in 5 by 12 inch sticks is used in blasting the drill holes. No. 6 detonators, and plain and single countered cordeau are used. The speed of the fuse, which is of the safety type, is about 1 f.p.m. No primers are used. Springing is unnecessary due to the size of the hole. The cordeau is lowered with the first cartridge, the remaining cartridges are tamped in, and the hole is filled with limestone screenings. About a foot of cordeau is left extending above ground to tie into the lead wire for firing.

One crew consisting of four men - powder foreman, driller and two helpers - load, tamp, and fire. The time required for loading 35 holes is approximately 4 hours. Each hole takes roughly a 75-pound charge of explosive.

The fragmentation obtained varies from pieces of rock less than an inch in maximum diameter to 6 or 8 foot bowlders. The use of a large primary crusher reduces secondary blasting to a minimum.

Secondary Blasting

The amount of secondary blasting depends to a great extent on what part of the quarry is being worked - in other words, on the extent to which joints prevail and the angle at which they approach the bench. From 10 to 20 per cent of the stone requires secondary blasting.

Blockholing is the method used in secondary blasting, although mud capping is resorted to at times. One and one-quarter inch holes are drilled with an Ingersoll-Rand, style 430, butterfly jackhamer. Forty per cent N. G. dynamite in 1½ by 8 inch sticks and safety fuse with a burning speed of 1 f.p.m. are employed. One hole is usually sufficient for each bowlder. The secondary blasting is done by 3 men from the shovel crew as the work becomes necessary.

The quantity of explosive used for primary blasting averages about 75 per cent of the total which is approximately 1/5 pound, costing 2½ cents per ton of stone broken.

Loading Stone

Two steam, railway-type shovels equipped with 2 and 2½ yard dippers, respectively, are used for loading the stone. These shovels are operated by 6 men to the shovel, the crew consisting of an engineer, craneman, fireman, and three pitmen. The three pitmen act as secondary-blasting men and are supervised by the engineer or quarry foreman.

The selection of steam shovels was primarily due to the lack of other power facilities at the time the plant was erected. It is recognized that electrical equipment might be more economical, but a replacement is not deemed advisable at this time.

The stone and the waste at the quarry are all loaded together, the separation being made in the plant. The shovels load 5 cars of 7-tons capacity each in about 7 minutes, or about 2,000 tons of rock per day for the two shovels. The shovels are capable of loading 3,000 tons, but the plant will not take care of this quantity.

Transportation to Crusher

A sketch of the quarry cars in use is shown in Figure 2.

The transportation of the stone from the quarry is taken care of by 2 H. K. Porter, 18-ton, saddle-type, standard-gage steam locomotives with 4-wheel drive. These locomotives each pull 5 flat-bottom cars with upright sides and having a capacity of 7 tons each up a 3 per cent grade to the crusher, and return them to the quarry over the same track. The haul may vary from ¼ to 1 mile, depending on where the shovels are working. The cars are delivered directly to the crusher and are side dumped into the crusher mouth. The cars are Western Wheel and Scraper type and have bodies lined with steel plate.

The permanent tracks are of 75-pound rails and the movable tracks are of 65-pound steel. The various tracks and sidings on the property are shown in Figure 1.

Each locomotive has one operator or engineer who does all the work - firing, taking water, lubricating cars, etc. The fuel used is a topped crude oil purchased from a nearby refinery in tank cars.

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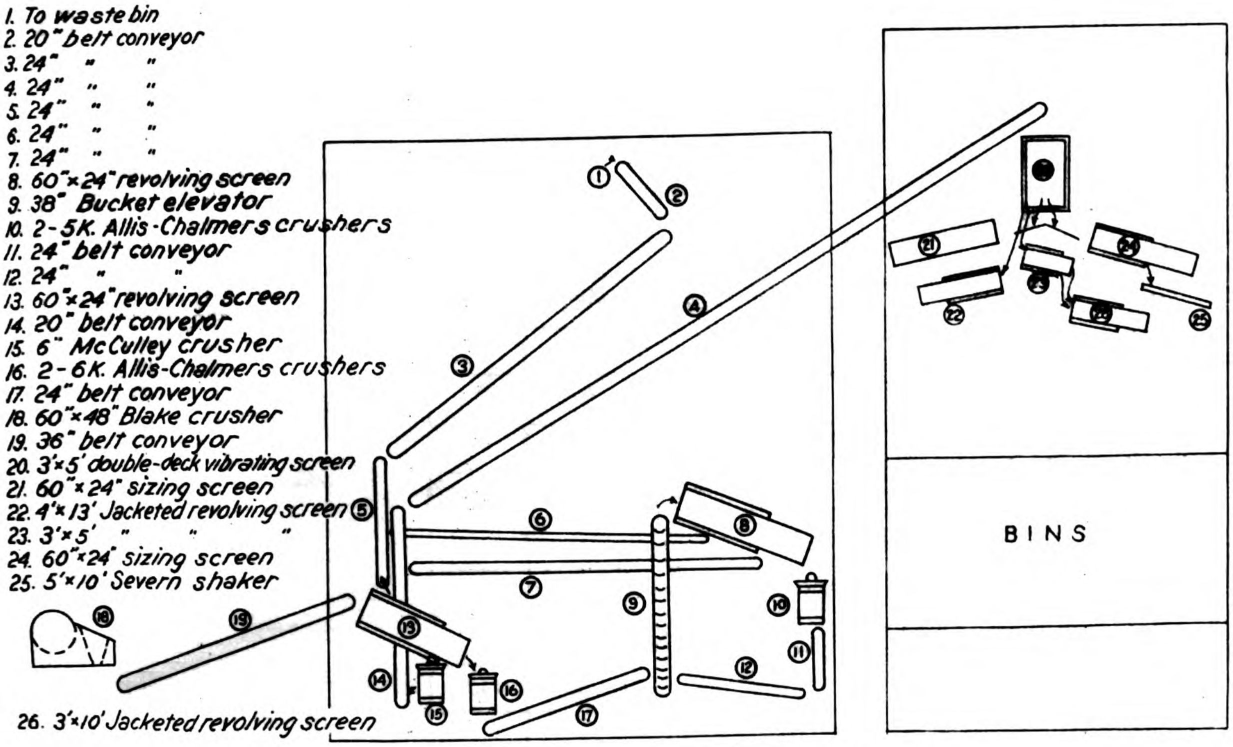
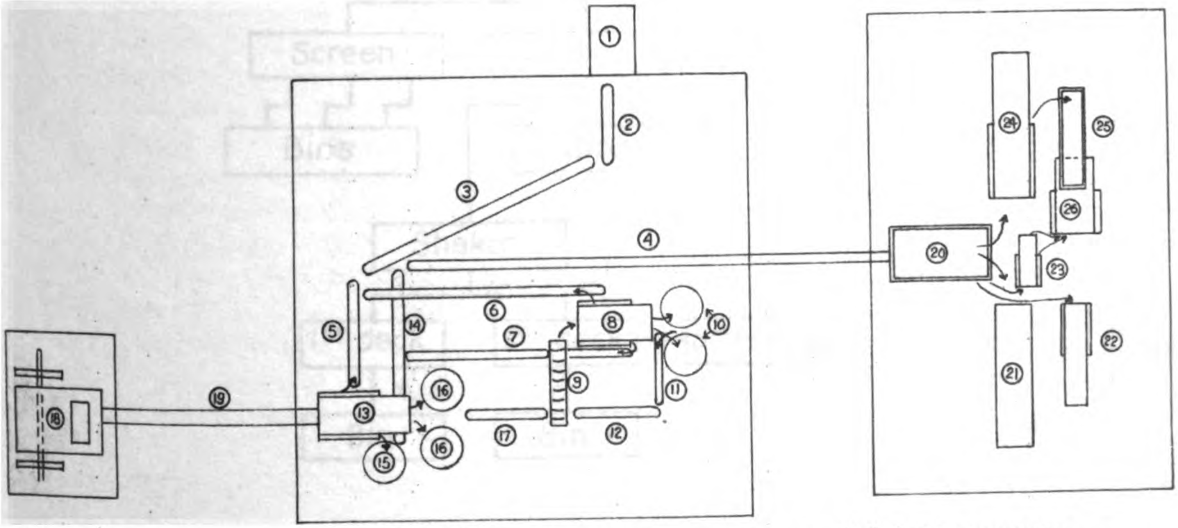

1. To waste bin
2. 20" belt conveyor
3. 24" " "
4. 24" " "
5. 24" " "
6. 24" " "
7. 24" " "
8. 60"×24" revolving screen
9. 38" Bucket elevator
10. 2-5K. Allis-Chalmers crushers
11. 24" belt conveyor
12. 24" " "
13. 60"×24" revolving screen
14. 20" belt conveyor
15. 6" McCulley crusher
16. 2-6K. Allis-Chalmers crushers
17. 24" belt conveyor
18. 60"×48" Blake crusher
19. 36" belt conveyor
20. 3'×5' double-deck vibrating screen
21. 60"×24" sizing screen
22. 4'×13' Jacketed revolving screen
23. 3'×5' " " "
24. 60"×24" sizing screen
25. 5'×10' Severn shaker
26. 3'×10' Jacketed revolving screen
BINS

Figure 3.- Elevation of crushing plant



1. Waste bin
2. 20" belt conveyor
3. 24" " "
4. 24" " "
5. 24" " "
6. 24" " "
7. 24" " "
8. 60"×24" revolving screen
9. 38" Bucket elevator
10. 2-5K Allis-Chalmers crushers
11. 24" belt conveyor
12. 24" " "
13. 60"×24" revolving screen
14. 20" belt conveyor
15. 6" McCulley crusher
16. 2-6K. Allis-Chalmers crushers
17. 24" belt conveyor
18. 60"×48" Blake crusher
19. 36" belt conveyor
20. 3'×5' double-deck vibrating screen
21. 60"×24" sizing screen
22. 4'×13' Jacketed revolving screen
23. 3'×5' " " "
24. 60"×24" sizing screen
25. 5'×10' Severn shaker
26. 3'×10' " " "

Figure 4.- Plan of crushing plant

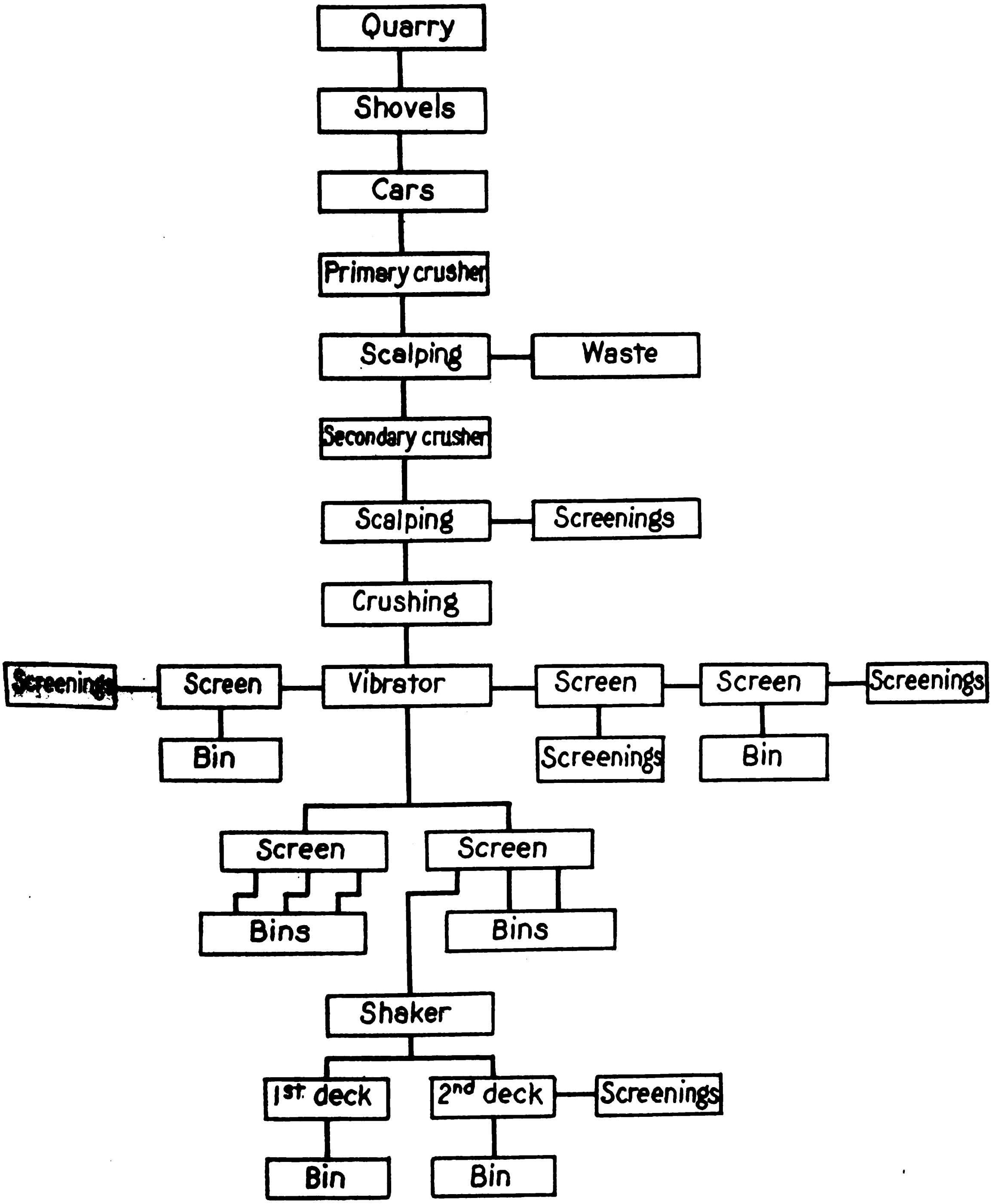


Figure 5.- Flow sheet of plant

Drainage

The quarry has natural drainage. The water flows from the quarry to a stream which is well below the floor level and within 50 feet of the quarry's edge.

CRUSHING PLANT

Plans and details of the crushing plant are shown in Figures 3 and 4.

Car Unloader

The loaded quarry cars are dumped into the primary crusher by a Curtis airhoist having an 8-inch diameter and 6-foot stroke and exerting a 5-ton lift with 80 pounds of air pressure The air compressor is a belt-driven compressor having a 10 by 10 inch cylinder and making 275 r.p.m.

The cars are spotted above the crusher by the locomotives and are lowered to the crusher for dumping by a cable attached to the upper car and running off a drum controlled by an air-pressure clutch. The cable is rewound on the drum by a 50-hp. squirrel-cage motor. This mechanism was made locally and although not of the best it answers its purpose satisfactorily.

Flow of Stone

A flow sheet of the plant is shown in Figure 5.

After being discharged into the primary crusher the stone takes the following route:

1. 60 by 48 inch Blake jaw crusher.
2. 36-inch conveyor belt.
3. 60-inch by 24-foot Allis-Chalmers revolving scalping screen.
4. 24-inch conveyor belt.
5. 2 No. 6K Allis-Chalmers gyratory crushers.
6. 6-inch McCully gyratory crusher.
7. 20-inch conveyor belt.
8. 24-inch conveyor belt.
9. 38-inch bucket elevator.
10. 60-inch by 24-foot Allis-Chalmers revolving scalping screen.
11. 2 No. 5K Allis-Chalmers gyratory crushers.
12. 24-inch conveyor belt.
13. 24-inch conveyor belt.
14. 36-inch by 5-foot vibrating screen.
15. 2, 60-inch by 24-foot sizing screens.
16. Screens for sizing small materials.
17. Storage bins.

Primary Crusher

The primary breaker is a 60 by 48 inch Blake jaw crusher. It is set with a discharge opening of 8 inches and is driven by a 200-hp. induction motor. Electric power is now furnished by transmission lines from the Eastland plant of the Texas Electric Service Corporation. The size of stone fed ranges from a fraction of an inch up to the largest size the crusher will take.

36-Inch Conveyor Belt

The discharge from the primary crusher which varies in size from less than an inch to 8 inches in diameter is carried by a 36-inch rubber-covered conveyor belt a distance of 142 feet. The conveyor is driven by belt from a main line shaft which serves other conveyors, revolving screens, and crushers, and which is driven by a 150-hp. induction motor.

60-Inch by 24-Foot Revolving Screen

The revolving screen is fed from the primary crusher by the 30-inch belt conveyor. It has round perforations ranging from 3½ to 2 inches in diameter, and is jacketed two-thirds of its length with a ⅜-inch square-mesh screen. Material that passes the jacket goes to waste and that retained on the ⅜-inch screen goes to the 6-inch McCully crusher with the coarse material from the screen. During wet weather, however, all stone through the 2-inch screen goes to waste to eliminate the dirt, clay, etc., that does not pulverize due to the dampness. The power for the screen is delivered from the same line shaft that drives the 30-inch conveyor from the primary crusher.

Waste-Stone Conveyor

This is a 24-inch rubber-belt conveyor that takes the waste material from the first scalping screen and also the ⅜-inch screenings from the second scalping screen when there is no demand for this class of material. The ⅜-inch screenings when salable are stored in bins.

This conveyor is 160 feet long and is belt-driven by a 10-hp. induction motor.

No. 6K Gyratory Crusher

There are two No. 6K Allis-Chalmers gyratory crushers fed by gravity from the revolving screen. The discharge of each crusher has an opening of 3½ inches from which the stone is delivered directly to a 24-inch belt conveyor. The drive is from the main line shaft by belt.

Six-Inch McCully Gyratory Crusher

The 6-inch McCully crusher is fed from the scalper, receiving the 3½ to 2 inch oversize. The discharge opening is 2¼ inches and the crusher is driven by belt from the main line shaft.

McCully Belt Conveyor

This is a 20-inch rubber-belt conveyor receiving the discharge from the McCully 6-inch crusher. It is 40 feet long and discharges onto the 24-inch conveyor carrying the crushed stone to the sizing screens. It is driven by a 7½-hp. Allis-Chalmers motor.

Allis-Chalmers Crusher Conveyor

The discharge from the 6K Allis-Chalmers crusher is handled by a 24-inch rubber-belt conveyor, 20 feet long, driven by a 7½-hp. motor. It discharges to the 38-inch bucket elevator.

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Bucket Eletator

This elevator is 40 feet high and carries 38-inch buckets. It elevates the crushed material from the 6K Allis-Chalmers crusher conveyor to the second scalping screens, and has a slope of about 60°. The elevator is belt-driven from the main line shaft through reduction gears to obtain the desired speed.

Second Scalping Screen

This is a 60-inch by 24-foot Allis-Chalmers revolving screen having 5 sections - 4 sections with 2-inch perforations and one section with 2½-inch perforations. The four sections with 2-inch holes are jacketed with ⅜-inch mesh screen. The screenings go to either the waste bin or the screenings bin, depending on market conditions. The material retained on the ⅜-inch screen goes to the sizing screen via the 24-inch conveyor along with other materials for the same destination. The stone retained on the scalping screen is discharged by gravity directly into two 5K Allis-Chalmers crushers. The scalping screen is powered from the main-line shaft.

5K Allis-Chalmers Crushers

There are two 5K Allis-Chalmers gyratory crushers that receive the stone from the second scalping screen. Their discharge openings are set at 2¼ inches. The discharge from the crushers is returned to the 38-inch bucket elevator by two 24-inch conveyors and thence to the second scalping screen, thus forming a closed circuit. Power for these crushers is supplied from the main-line shaft by belt drive.

Conveyors from 5K Crushers

A 24-inch belt conveyor takes the discharge from the two 5K Allis-Chalmers crushers and delivers it to another 24-inch belt conveyor traveling at right angles, which carries the material to the 38-inch bucket elevator and then to the second scalping screen. The conveyors are driven by a 7½-hp. motor.

Screenings Conveyor

The screenings from the second scalping screen are handled by a 24-inch belt conveyor 60 feet long that can discharge all or part of the material to either the conveyor going to the sizing screen or to the waste bin, depending on the demand for material of this size. The conveyor is driven by a 10-hp. motor.

Vibrating Screens

The crushed material for the sizing screens is delivered by a 24-inch rubber-belt conveyor to a 3 by 5 foot Link Belt, double-deck, vibrating screen, having an upper deck of ⅞-inch square mesh and a lower deck of ⅜-inch mesh screen. The undersize through the ⅞-inch screen goes to the ⅜-inch screen and the oversize on the ⅜-inch screen is discharged through a chute to a smaller revolving screen for further separation and cleaning from dust. The undersize from the ⅜-inch screen also goes to a revolving screen for further separation. The oversize on the ⅞-inch screen is discharged, split, and fed to the revolving sizing screens. The vibrating screen is belt-driven by a 7½-hp. motor.

Two Sizing Screens

These two 60-inch by 24-foot Allis-Chalmers sizing screens receive the oversize from the upper deck of the Link-Belt vibrating screen. There are 6 sections in each screen with perforations varying from 1 inch to 2 inches, as shown in Figure 5. The sized stone is chuted to storage bins.

These two large sizing screens, together with 3 small revolving screens in the screen room, are driven from a line shaft by a 100-hp. induction motor.

The east screen has a ¾-inch square-mesh jacket for 12 feet of its length. Each of the 6 sections of both the east and west screens is 4 feet long and has round holes. Beginning at the feed-end of the screens, the size of perforations are as follows:

Size of perforations, inches

Section	East screen	West screen
1	1	1
2	1⅜	1¼
3	1⅜	1¼
4	2	1½
5	2	1½
6	2	2

The undersize from the first three sections of the east screen discharges into the jacket and is taken care of as described later. Sections 4 and 5 supply the same bin with a plus 1⅜ minus 2-inch products. The undersize from section 6 and the overall rejects go to a separate bin and range from about 2-inch size up to whatever size is demanded, the maximum size being regulated by the setting of the crusher, which is usually 1½ inches.

The undersize from the first three sections of the west screen go to the same stone bin, and the combined product is classified as 1¼ over ⅞ inch. The undersize of the fourth and fifth sections supply 1½ over 1-inch stone. Section 6 turns out the same products as section 6 of the east screen.

Screens for Sizing Small Materials

There are four fine screens, three revolving and one vibrating, that further separate the small material coming from the two large sizing screens.

1. The undersize from the lower deck, ⅜-inch mesh, of the vibrating screen is received by a 3 by 5 foot, jacketed, revolving screen. The inside drum has 3/16 inch square mesh and the jacket has ⅛-inch square mesh. The undersize from the ⅛-inch screen goes to the dust bin, and the material retained on both the ⅛ and 3/16 inch screen is discharged into a 3 by 10 foot, jacketed, revolving screen with an inside screen of ¼-inch mesh and with a 3/16-inch mesh jacket. These further eliminate the dust. The undersize from both the inside screen and jacket go to the same bin as a commercial minus ¼ inch plus 10-mesh product.

2. The undersize from the ⅜-inch vibrating screen discharges into a 4 by 13 foot jacketed revolving screen. The inside screen is ½-inch square mesh and the jacket is ¼-inch square mesh. The undersize from the ¼-inch screen goes to the dust bin and the oversize goes to a bin as a minus ½ plus ¼ mesh product.

3. One of the large sizing screens has a ¾-inch mesh jacket for 12 feet of its length. The undersize from this jacket is discharged to a 5 by 10 foot, double-deck Severns shaker

screen that is driven by a 10-hp. motor. The upper deck has ⅝-inch round perforations and the lower deck ¼-inch perforations. The undersize from the ¼-inch deck goes to the dust bin, and the oversize is delivered to the minus ⅝ plus ¼ inch commercial bin. The oversize from the ⅝-inch deck goes to the minus ¾ plus ⅝ inch bin. The oversize from the large sizing-screen jacket is directed into the minus 1⅜ plus ¾ inch commercial bin. When specifications do not exact a thorough separation the various sizes from 1⅜-inch down to ¼-inch can be and sometimes are delivered to the same bin and considered as minus 1⅜ plus ¼ inch commercial stone.

Approximate tonnage passing each screen, by sizes

	Tons per hour
First scalping screen	
Minus ⅝-inch	30
Plus ⅝-inch	170
Total	200
Second scalping screen	
Minus ⅜-inch	12
Plus ⅜-inch	158
Total	170
Vibrating screen	
Upper deck:	
Minus ⅞-inch	20
Plus ⅞-inch	138
Total	158
Lower deck:	
Minus ⅜-inch	4
Plus ⅜-inch	16
Total	20
3 by 5 foot revolving jacketed screen	
Inner jacket:	
Minus 3/16-inch	2
Plus 3/16-inch	2
Total	4
Outer jacket:	
Minus ⅛-inch	1
Plus ⅛-inch	1
Total	2
3 by 10 foot revolving jacketed screen	
Inner jacket:	
Minus ¼-inch	2
Plus ¼-inch	1
Total	3
Outer jacket:	
Minus 3/16-inch	1
Plus 3/16-inch	1
Total	2

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Approximate tonnage passing each screen, by sizes - Continued

	Tons per hour
4 by 13 foot revolving jacketed screen	
Inner jacket:	
Minus ½-inch	9
Plus ½-inch	7
Total	16
Outer jacket:	
Minus ¼-inch	4
Plus ¼-inch	5
Total	9
West 60-inch by 24-foot revolving screen	
Oversize and undersize of section 6:	
Minus 2½ plus 1½ inch	45
Through sections r and 5:	
Minus 1½ plus 1 inch	8
Through sections 1, 2 and 3:	
Minus 1¼ plus ⅞	17
Total	70
East 60-inch by 24-foot revolving screen	
Oversize and undersize of section 6:	
Minus 2½ plus 2 inch	32
Through sections 4 and 5:	
Minus 2 plus 1⅜ inch	11
Through sections 1, 2 and 3:	
Minus 1⅛ plus ¾ inch	15
Through ¾-inch jacket:	
Minus ¾-inch	10
Total	68
5 by 10 foot double-deck shaking screen	
Upper deck:	
Minus ⅜-inch	50
Plus ⅜-inch	50
Total	100
Lower deck:	
Minus ¼-inch	20
Plus ¼-inch	30
Total	50

Summary

The output consists of 10 sizes of material. From 2,000 tons of crushed stone the following products are obtained:

Products obtained from crushed stone

Product	Tons per 2,000 tons stone	Per cent of total
Minus 2½ plus 2 inch	770	38.5
Minus 2 plus 1⅞ inch	110	5.5
Minus 1½ plus 1 inch	80	4.0
Minus 1⅝ plus ¾ inch	150	7.5
Minus 1¼ plus 1 inch	170	8.5
Minus 1 plus ½ inch	70	3.5
Minus ¾ plus ⅝ inch	50	2.5
Minus ¾ plus ¼ inch	50	2.5
Minus ⅝ plus ¼ inch	30	1.5
Minus ¼ plus 10 mesh	20	1.0
Commercial stone	1,500	75.0
Waste	500	25.0
Total	2,000	100.0

Figure 6 shows details of sizing screens and bins.

Bins

The bins are so arranged that the various materials may be mixed to accommodate demands for any specific size or range of sizes. Their contents can be drawn off separately by gates leading directly through chutes into cars. One man handles all the loading.

Buildings

A separate building houses the primary crusher. This is a small, wood-frame structure covered with corrugated iron, having 1,500 square feet of ground area and 37,500 cubic foot volume.

The secondary crushing and scalping-screen building has 7,200 square feet of floor space and a volume of 360,000 cubic feet. This building also has a wooden frame with corrugated-iron sides and roof, and concrete foundations.

The screen and bin house has 8,800 square feet of floor area and a volume of 570,000 cubic feet.

The three buildings are connected by conveyor sheds which are constructed of the same materials as the buildings and which rest on concrete foundations.

Storage

No storage facilities are provided other than the bins, but the quarry floor is excellently suited for storage. All waste is stored or dumped near the plant and is transported from the waste bins by rail in 2-yard, side-dump, steel cars. The haulage is done by an electric mining-hoist engine, using a ½-inch steel cable and a 100-hp. induction motor. Disposal of the waste and screenings is also accomplished by means of a Brown-hoist locomotive crane. The material is loaded into regular railway-type cars from the bin and hauled to the point of unloading where the Brown-hoist discharges the cars. The Brown-hoist carries a 1-yard clamshell bucket and a 40-foot boom. About 40 minutes is required to unload a 50-ton car.

Yard Haulage

The general yard haulage is done by a 50-ton, saddle-type, 4-wheel drive American locomotive. The main duty of this locomotive is to haul the empty and loaded cars to and from the main-line switch of the Texas and Pacific Railroad at Tiffin, which is about ¼ mile distant. All hauling of screenings, waste, rip rap, etc., is also done by this locomotive.

The loading yard has accommodations for the storage of 65 cars. There are approximately 7 miles of track inside the quarry.

Scale House

The stone is weighed on a 150-ton Howe scale by the loader, who is a certified weigher. The car loader has an assistant who cleans and patches the cars to prevent waste in transit.

MISCELLANEOUS SERVICE

Air Compression

Compressed air is used for secondary drilling, drill sharpening, lowering and spotting quarry dump cars at the primary crusher, blowing and cleaning motors, pneumatic tools, etc. The main air supply is obtained from a 10 by 10 inch Ingersoll-Rand compressor, making 275 r.p.m. and delivering air at 100-pound pressure. In addition there are two 11 by 12 inch locomotive-type Westinghouse air-brake compressors mounted on the two steam shovels, which supply air for secondary drilling.

Machine, Blacksmith, Welding, and Woodwork Shop

All the shop work is done in one building.

Most parts are ordered in the rough and machined down to requirements, especially such parts as bushings, shafting, collars, axles, pistons, piston rings, drill stems, bearings, and such other materials as can be handled similarly.

The equipment of the shop includes:

1 lathe; 20-inch by 12-foot, Lodge and Shipley, cone-pulley drive, double back-geared, and driven from line shaft.

1 planer and shaper; No. 26, Whip Co. combination, open-side and driven from line shaft, cone-pulley drive.

1 drill press; heavy-duty, 24-speed, forward and reverse, radial drill with No. 5 Morse taper in spindle, simple pulley speed-box type with plain box table. Driven from line shaft.

1 14-inch U. S Sensitive floor drill with No. V-2 taper in spindle furnished, 2 tables and cup, and crotch centers. Driven from line shaft.

1 Van Dorn electrical, pedestal-type, ball-bearing grinder equipped with two 8 by ¾ inch carborundum stones.

1 Van Dorn electrical, pedestal-type, ball-bearing grinder equipped with two 12 by 1½ inch carborundum stones.

- 1 Racine No. 1, high-speed, metal-cutting machine, belt driven, with 6 by 6 inch capacity.
- 1 No. 316-A Oster power-driven combination pipe and bolt threading machine, with automatic die release.
- 1 No. 225, 36-inch, Sidney band saw, rubber-covered wheels, belt driven, tight and loose pulley, equipped with 1-inch and ½-inch blades.
- 1 box electric, 10-ton traveling crane with 20-foot span and 15-foot lift, operated from the floor.
- 1 steam hammer.
- 3 work benches equipped with vises.
- 1 blacksmith's forge equipped with ¼-hp. motor-driven fan.
- 1 18-inch circular rip saw.
- 1 30-inch circular rip saw mounted on mantle tables.
- 1 2-ton revolving chain hoist.
- 1 oxygen-acetylene welding and cutting outfit.
- 3 pneumatic riveting hammers.
- 1 pneumatic chipping hammer.
- 1 pneumatic drill.
- 1 electric drill.
- 1 35-hp. locomotive-type boiler for shop service.
- An assorted line of jacks, jigs, and tools.

Due to the rather isolated location of the quarry this well-equipped shop pays for itself.

The personnel of the shop consists of 1 shop foreman, 1 machinist, 1 blacksmith, 1 blacksmith's helper, 1 welder, and 1 carpenter.

Power

Originally the plant had its own power plant consisting of two 250-hp. Casey-Hedges boilers driving a turbo-generator, which develops a maximum of 625 kilowatt with a power factor of 80 per cent at 3,600 r.p.m. Since 1923 all power has been purchased from the Texas Electric Service Co. Power costs are distributed on the basis of rated horsepower and the hours worked by each motor.

Auxiliary Yard Equipment

One 2½ by 2 inch, 4-stage, type-V, house-fitted, horizontal centrifugal pump, driven directly by a 30-hp., 3,500-r.p.m., Allis-chalmers, squirrel-cage motor, supplies water under pressure to the entire plant.

One 9 by 12 inch steam pump is used for unloading oil from tank cars to storage tanks and for pumping oil from the storage tank to the locomotives and Brownhoist. This pump is run by steam from a 20-hp. upright boiler which is also utilized in cold weather for preheating fuel oil.

There are two fuel-oil storage tanks, with 8,000-gallon capacity each, which hold fuel for the locomotives and the Brownhoist. The shovel boilers and stationary boilers are fired with natural gas from the near-by gas fields through temporary pipe lines.

The water supply comes from a privately owned lake. Before use in the boilers the water is chemically treated in a 1,600-barrel tank to prevent priming and scaling, and after settling is drawn off into another 1,600-barrel tank for direct transfer to the various boilers.

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The dynamite is stored in a concrete-and-steel cellar about ½ mile from the quarry and is brought to the job by truck.

GENERAL PLANT EXPENSE

Superintendence

Superintendence includes the salary of the superintendent, quarry foreman, night watchman, clerks, general supervision and office work, and all expense in connection with the safety program.

Office and Warehouse

The office and warehouse expense includes the cost of materials, supplies, and maintenance of equipment for this particular department.

Maintenance of General Buildings

The general-buildings expense includes the cost of upkeep of camp dwellings, dynamite house, water and oil storage tanks, office and warehouse buildings, oil-and-paint storage house, change house, etc.

Automobile and Truck

This item consists of the upkeep of automobiles and trucks.

Miscellaneous

Miscellaneous expense includes all general expenses that can not be definitely allocated, such as that for yard cleaning, janitor work, etc.

Group Life Insurance

After an employee has been with the company for one month he is eligible for a group life policy, the principal of which increases with length of service as follows:

Length of employment	Insurance
1 to 6 months	$200
6 months to 1 year	300
1 to 1½ years	400
1½ to 2 years	500
2 to 2½ years	600
2½ to 3 years	700

and so on up to a maximum of $1,000. The premiums are paid by the company.

Pay System

All employees are paid twice a month on an hourly basis; the superintendent, quarry foreman, watchman, and clerk are paid a monthly salary. During a year the quarry is operated about 275 days of 10 hours each, or an average of 53 hours per week. The average hourly wage is 47 cents.

The only contract work is the removal of overburden, as previously mentioned. No bonus system is in force.

SAFETY METHODS

Steps were taken in 1926 to inaugurate a safety program. A general safety committee, consisting of senior members of the company, and a safety council committee at the plant including the superintendent, quarry foreman, and the foreman of each department, were organized. Meetings are held monthly, at which time reports are read and discussed, and means of preventing accidents are considered.

Before a new employee is placed on the payroll, he is examined by the company's physician and directed to read a pamphlet of instructions on safety methods. On the employees application blank he is required to give in detail his past record for several years. After employment he is especially coached in his duties with a view toward safety and he is supposed to attend safety meetings.

The frequency rates of accidents for the past three years are:

1928	78.5
1929	56.0
1930	32.0

ORGANIZATION

The superintendent is in charge of all operations and he appoints foremen and other department heads after consultation with the vice president. The superintendent is aided by an assistant, who is the quarry foreman.

Figure 7 shows the quarry organization chart.

The personnel of the plant is as follows:

		Average number of men
Stripping (by contract)		4
Drilling		3
Secondary drilling		1
Loading to quarry cars		6
Shovel pitmen		5
Transporting to crusher		3
Primary crushing		3
Scalping and secondary crushing		5
Screening		1
Waste disposal		2
Main railroad (track men)		5
Loading crew		4
Brown hoist		1
Machine shop		6
Rip-rap loaders (extra help)		4
General Administration:		
Superintendent	1	
Quarry foreman	1	
Watchman	1	
Clerk	1	
Truck driver	1	
Janitor	1	6
		59

SUMMARY OF COSTS
(Period - 1929)

Tiffin Quarry

Total overburden stripped	7,700 cubic yards
Total stone mined	443,325 tons
Crushed and sold	308,571 tons
Waste, screenings, and loss	134,754 tons

	Amount	Per-ton costs	
		Based on 443,325 tons mined	Based on 308,571 tons sold
Stripping (contract) and rental of land	$11,924.20	$0.0269	$0.0387
Drilling and blasting[1]	27,063.50	.0610	.0877
Shovel and loading[2]	39,717.20	.0896	.1287
Total cost of rock loaded in quarry cars	78,704.90	0.1775	0.2551
Transportation to jaw crusher[3]	16,484.82	.0372	.0534
Jaw-crusher expense[4]	9,797.20	.0221	.0318
Secondary crushing and screening	27,312.37	.0616	.0885
Waste disposal	4,611.22	.0104	.0149
Loading and switching	14,497.49	.0327	.0470
Superintendence and general plant expense	13,096.34	.0295	.0424
Total operating costs	164,504.34	0.3710	0.5331

[1] Includes all expenditures for primary and secondary drilling and blasting before shovel operations.

[2] Includes cost of some explosives used during shovel operations.

[3] Includes maintenance of locomotive, cars and tracks.

[4] Includes cost of some pop shots at crusher.

DETAILED COST - DIRECT OPERATIONS

(Period - 1929)

	Amount	Costs per ton		Cost per cubic yard of stripping based on 7,700 cubic yards removed
		Based on 443,325 tons mined	Based on 308,571 tons sold	
Stripping expense:				
Let by contract	$8,924.20	$0.0201	$0.0289	$1.159
Royalty to landowners	3,000.00	.0068	.0098	.390
Total stripping	11,924.20	0.0269	0.0387	1.549
Drilling and blasting:				
Operating labor	5,849.48	.0132	.0190	-
Fuel (gasoline)	1,886.70	.0043	.0061	-
Water	117.00	.0002	.0004	-
Lubricants and supplies	90.65	.0002	.0003	-
Repair labor and material	2,465.89	.0056	.0080	-
Explosives	16,653.78	.0375	.0539	-
Total drilling and blasting	27,063.50	0.0610	0.0877	-
Shovel and loading expense:				
Operating labor	13,424.36	.0303	.0435	-
Gas (natural)	5,076.97	.0115	.0164	-
Power	417.00	.0009	.0014	-
Water	654.44	.0015	.0021	-
Lubricants and supplies	986.98	.0022	.0032	-
Maintenance of shovels	10,556.98	.0238	.0342	-
Maintenance of lines	1,242.90	.0028	.0040	-
Changing shovel tracks	2,798.16	.0063	.0091	-
Explosives (secondary)	4,559.41	.0103	.0148	-
Total shovel and loading expense	39,717.20	0.0896	0.1287	-
Transportation expense:				
(From quarry to jaw crusher)				
Operating labor	3,892.21	.0088	.0126	-
Fuel oil	3,504.70	.0079	.0114	-
Gas	526.80	.0012	.0017	-
Water	337.33	.0008	.0011	-
Lubricants and supplies	243.01	.0005	.0008	-
Maintenance locomotives	2,525.90	.0057	.0082	-
Maintenance dump cars	3,110.24	.0070	.0100	-
Maintenance tracks	2,344.63	.0053	.0076	-
Total transportation	16,484.82	0.0372	0.0534	-

DETAILED COST - DIRECT OPERATIONS - Continued

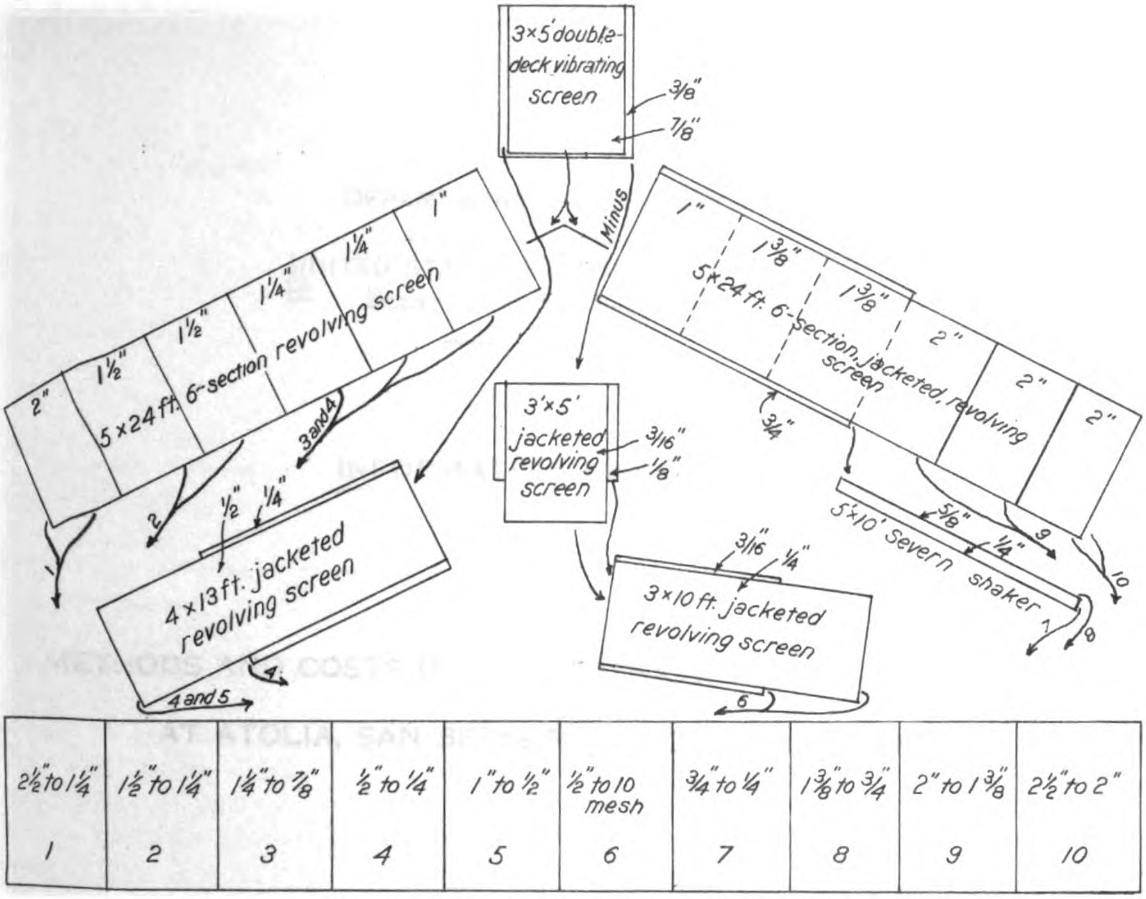
(Period - 1929)

		Costs per ton	
	Amount	Based on 443,325 tons mined	Based on 308,571 tons sold
Jaw crusher:			
Operating labor	$2,731.54	$0.0062	$0.0089
Power	1,749.86	.0039	.0057
Water	112.00	.0003	.0004
Lubricants and supplies	717.99	.0016	.0023
Maintenance machinery	3,886.78	.0087	.0125
Maintenance buildings	112.76	.0003	.0004
Explosives (pop shots)	486.27	.0011	.0016
Total crusher	9.797.20	0.0221	0.0318
Secondary crushing and screening expense:			
Operating labor	8,935.62	.0202	.0290
Power	9,733.22	.0219	.0315
Lubricants and supplies	991.42	.0022	.0032
Maintenance machinery	7,481.49	.0169	.0242
Maintenance buildings	170.62	.0004	.0006
Total secondary crushing and screening	27,312.37	0.0616	0.0885
Waste disposal: (Screenings, clay, etc.)			
Operating labor	2,274.65	0.0052	0.0074
Fuel oil	495.50	.0011	.0016
Power	841.80	.0019	.0027
Lubricants and supplies	51.55	.0001	.0002
Maintenance of equipment	947.72	.0021	.0030
Total waste disposal	4,611.22	0.0104	0.0149
Loading and switching expense:			
Operating labor	5,639.79	.0127	.0183
Fuel oil	2,496.33	.0056	.0081
Gas	258.35	.0006	.0008
Water	337.35	.0008	.0011
Lubricants and supplies	182.50	.0004	.0006
Maintenance locomotives	2,425.19	.0055	.0079
Maintenance storage bins	340.20	.0008	.0011
Maintenance tracks and scales	2,817.78	.0063	.0091
Total loading and switching	14,497.49	0.0327	0.0470

SUMMARY OF COSTS PER TON

Period - 1929 Total rock handled 443,325 tons - Total rock recovered and sold 308,571 tons

Operating account	Labor		Fuel and gas		Water		Lubricants and supplies		Maintenance		Explosives		Power		Total	
	Per ton mined	Per ton sold	Per ton mined	Per ton sold	Per ton mined	Per ton sold	Per ton mined	Per ton sold	Per ton mined	Per ton sold	Per ton mined	Per ton sold	Per ton mined	Per ton sold	Per ton mined	Per ton sold
Stripping by contract and rental	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0.0269	$0.0387
Drilling and blasting	$0.0132	$0.0190	$0.0043	$0.0061	$0.0002	$0.0004	$0.0002	$0.0003	$0.0056	$0.0080	$0.0375	$0.0539	-	-	.0610	.0877
Shovel and loading	.0303	.0435	.0115	.0164	.0015	.0021	.0022	.0032	.0329	.0473	.0103	.0148	$0.0009	$0.0014	.0896	.1287
Cost of rock f.o.b. quarry cars	.0435	.0625	.0158	.0225	.0017	.0025	.0024	.0035	.0385	.0553	.0478	.0687	.0009	.0014	.1775	.2551
Transportation	.0088	.0126	.0091	.0131	.0008	.0011	.0005	.0008	.0180	.0258	-	-	-	-	.0372	.0534
Jaw crusher	.0062	.0089	-	-	.0003	.0004	.0016	.0023	.0090	.0129	.0011	.0016	.0039	.0057	.0221	.0318
Secondary crushing and screening	.0202	.0290	-	-	-	-	.0022	.0032	.0173	.0248	-	-	.0219	.0315	.0616	.0885
Waste disposal	.0052	.0074	.0011	.0016	-	-	.0001	.0002	.0021	.0030	-	-	.0019	.0027	.0104	.0149
Loading and switching	.0127	.0183	.0062	.0089	.0008	.0011	.0004	.0006	.0126	.0181	-	-	-	-	.0327	.0470
Superintendence and plant miscellaneous	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.0295	.0424
Total	0.0966	0.1387	0.0322	0.0461	0.0036	0.0051	0.0072	0.0106	0.0975	0.1399	0.0489	0.0703	0.0286	0.0413	0.3710	0.5331


3×5' double-deck vibrating screen
3/8"
7/8"
Minus
5×24 ft. 6-section revolving screen
2"
1½"
1½"
1¼"
1¼"
1"
3 and 4
2
1
4×13 ft. jacketed revolving screen
½"
¼"
4
4 and 5
3'×5' jacketed revolving screen
3/16"
1/8"
3×10 ft. jacketed revolving screen
3/16"
¼"
6
5×24 ft. 6-section, jacketed, revolving screen
1"
1⅜"
1⅜"
2"
2"
2"
¾"
5'×10' Severn shaker
5/8"
¼"
9
10
7
8

2½" to 1¼"	1½" to 1¼"	1¼" to 7/8"	½" to ¼"	1" to ½"	½" to 10 mesh	¾" to ¼"	1⅜" to ¾"	2" to 1⅜"	2½" to 2"
1	2	3	4	5	6	7	8	9	10

Figure 6.- Sizing screens and bin details

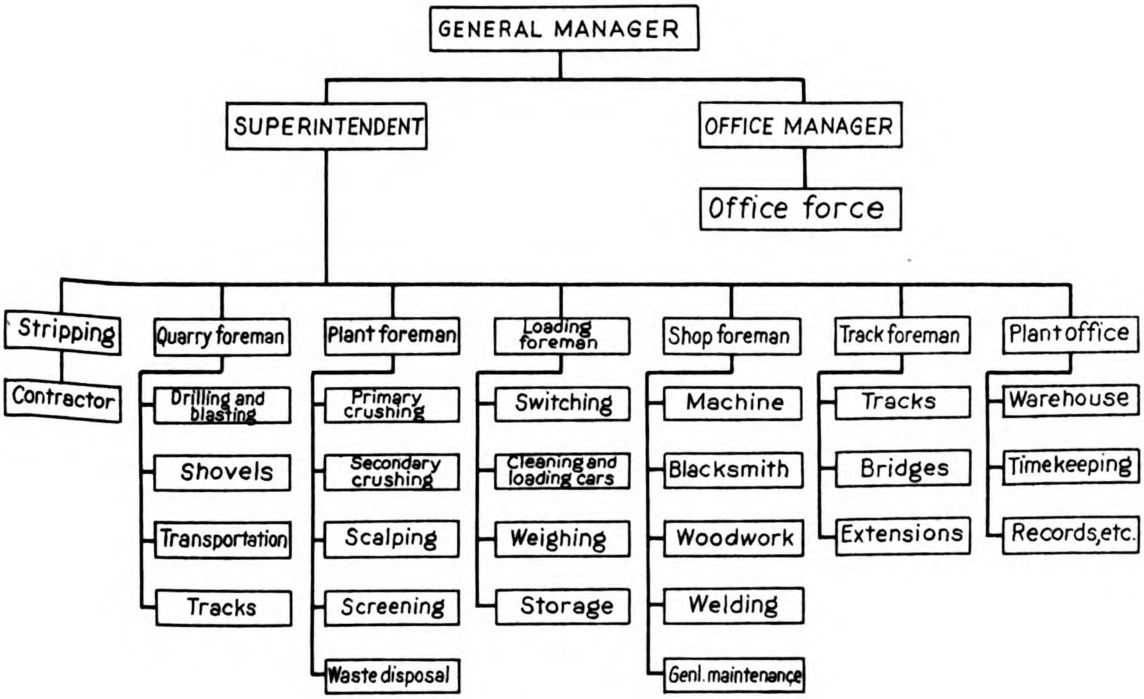


Figure 7.- Quarry-organization chart